Costs and Effectiveness of Strategies To Prevent Unintentional Childhood Injuries

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UNINTENTIONAL CHILDHOOD INJURIES

Injury is the leading cause of death to children after the first few months of life. In 1984, the latest year for which mortality data are available, 7850 children less than 15 years of age died from injury in the U.S. Some 398,000 children less than 15 years old were hospitalized as a result of injury in 1985, including 132,000 with fractures, 64,000 with intracranial injuries exclusive of skull fractures, and 38,000 with lacerations and open wounds (1). These are data from short-term hospital discharges and do not include multiple admissions to burn centers and other rehabilitative facilities. At the 1985 rate, about 1 in every 130 children is hospitalized for an injury annually. Assuming no repeat hospitalizations of the same child, about 1 of every 9 children born today would be hospitalized for injury during their first 15 years should there be no reduction in the current rates.

Fortunately, severe injury rates of children have declined in recent years. In 1980, 9703 children less than 15 years old died. Thus the 1984 deaths were 19 percent less than in 1980 while the population increased by 1 percent. Table 1 presents the death rates per 100,000 population for

Table 1. Death Rates Per 100,000 Population for Major Types of Injuries to Children in the United States, 1980-1984.

Motor Vehicles	Age				
	Under 1	1-4	5-9	10-14	All Ages
1980	7.0	9.2	7.0	8.1	23.5
1981	6.1	7.8	7.4	7.6	22.4
1982	5.8	7.9	6.5	7.0	19.7
1983	5.2	7.5	6.4	6.8	19.0
1984	4.4	6.9	6.2	7.1	19.6
Percent Change					
1980-1984	-37.1	-25.0	-11.4	-12.3	-16.6
Drowning					
1980	2.6	5.4	2.2	2.2	2.7
1981	2.0	5.0	2.0	2.0	2.3
1982	2.6	4.7	2.0	1.9	2.3
1983	2.3	4.7	2.0	1.9	2.2
1984	1.9	3.9	1.4	1.5	1.9
Percent Change					
1980-1984	-26.9	-27.8	-36.4	-31.8	-29.6

Table 1. (continued) Death Rates Per 100,000 Population For Particular Types of Injuries in the United States, 1980-1984

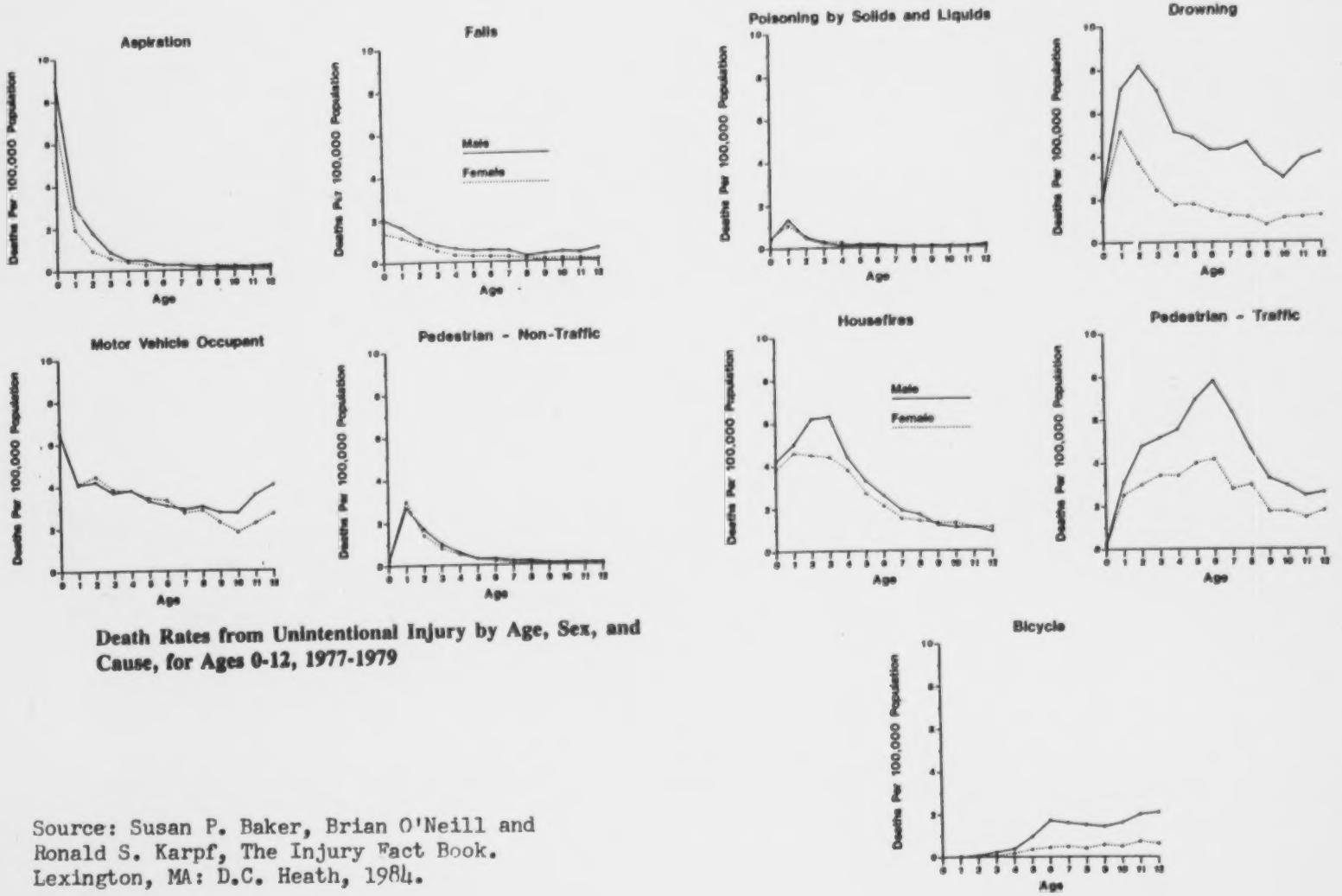
Fire	Age				
	Under 1	1-4	5-9	10-14	All Ages
1980	4.6	5.3	1.7	0.9	2.6
1981	3.8	5.4	1.9	0.9	2.5
1982	3.9	4.6	2.0	0.9	2.2
1983	3.1	4.6	1.6	0.9	2.1
1984	3.7	4.3	1.9	0.9	2.1
Percent Change					
1980-1984	-19.6	-18.9	10.5	0.0	-19.2
All Injuries					
1980	33.0	25.8	13.4	15.5	46.7
1981	27.3	23.6	14.0	14.4	43.9
1982	28.1	22.4	13.1	13.3	40.6
1983	26.0	21.8	12.4	13.0	39.5
1984	23.0	19.8	11.6	13.0	39.3
Percent Change					
1980-1984	-30.0	-23.2	-13.4	-16.1	-15.8

the major categories of injury deaths during the years 1980-1984. With the exception of deaths related to fires in children five years old or older, significant declines in mortality from injury have occurred. In the subsequent section on injury control programs, some evidence on the effects of those programs, such as child restraint laws, fencing of swimming pools, and use of smoke detectors, will be examined as probable contributors to these reductions.

The purpose of this review is to point to a model for injury control and the factors that contribute to success and failure of injury control efforts. The evidence on successful programs suggests that linkage of surveillance of injuries (specification of clusters and causes) with technical strategies for control can result in further acceleration of what is already a substantial success story.

Particular types of injuries tend to cluster in specific populations at various stages of growth and development in combination with particular environmental hazards. Figure 1 from The Injury Fact Book (2) indicates markedly different age and sex distributions of children's mortality rates for particular injuries. Deaths from aspiration of vomitus, food and objects placed in the mouth are high in infancy and decline exponentially with age. Motor vehicle occupant deaths decline very gradually with age. Deaths from falls,

FIGURE 1



Death Rates from Unintentional Injury by Age, Sex, and Cause, for Ages 0-12, 1977-1979

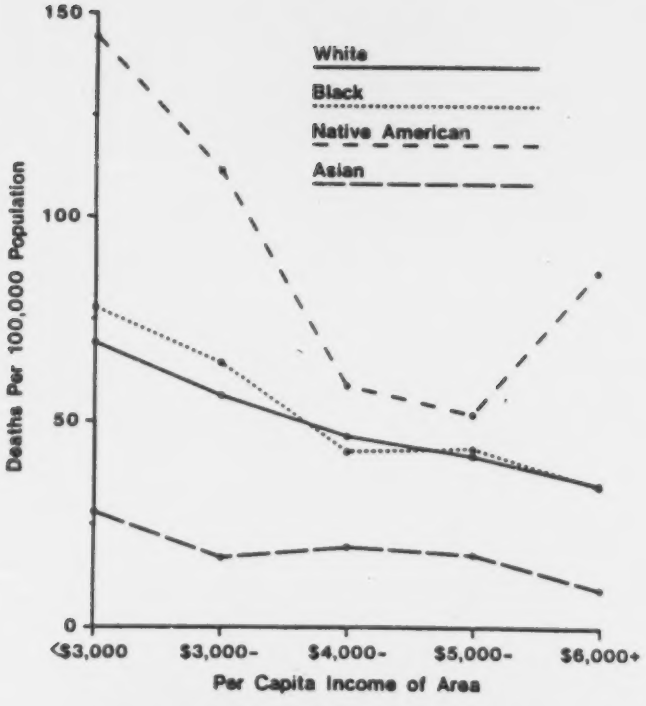
Source: Susan P. Baker, Brian O'Neill and Ronald S. Karpf, The Injury Fact Book. Lexington, MA: D.C. Heath, 1984.

pedestrians not in traffic (usually backed over in driveways), and poisonings are concentrated mainly in pre-schoolers. Housefire and drowning deaths peak at age two to three, but remain important in older children. Pedestrian deaths in traffic increase to age 6 and decline among older children. Bicyclist deaths begin to increase at age three and remain at about the same rate from ages 6 to 12. Males have higher rates than females in drownings, housefires, as pedestrians in traffic and using bicycles. This reflects a combination of increased exposure and, probably, some behavioral differences given exposure.

In general, persons of lower socioeconomic status have higher injury mortality rates. Figure 2 indicates a lower fatal injury rate per capita in areas with greater incomes. There are exceptions for particular types of injury. Children drowning in private swimming pools or crashing with parents in private aircraft are seldom in low income families. Low incomes are also associated with rural isolated populations which are at substantially greater risk both because of greater hazards (high speed travel, poor roads, farm machinery) and lack of quick emergency response.

Much less is known about nonfatal injuries. Although hospital discharge data indicate the type of injury, the cause is often not specified. Inclusion of the E-codes, from

FIGURE 2



Death Rates from Unintentional Injury by Per Capita Income of Area of Residence and Race, 1977-1979

Source: Susan P. Baker, Brian O'Neill and Ronald S. Karpf, The Injury Fact Book, Lexington, MA: D.C. Heath, 1984.

the International Classification of Diseases indicating source of injury, in the hospital discharge data would greatly facilitate the investigation and control of severe injuries. A few states and private sources have done more detailed data collection.

Data from Massachusetts indicates an annual rate of hospital admissions at 770 per 100,000 population of children and an emergency room treatment rate of 21,600 per 100,000 population. The death rate, 17 per 100,000 population, was substantially lower than the national rate. These data suggest ratios of about 45 hospitalizations and 1271 emergency room treatments for each death (3). The hospitalization rate for children's injuries in North Carolina, 800 per 100,000 population, was similar to that in Massachusetts (4).

Relevant Literature

Motor Vehicle Occupants. When a moving vehicle decelerates very rapidly in a crash or sudden stop, unrestrained occupants continue to move at the predeceleration speed until they contact interior or exterior surfaces. The extent of injury is a function of the speed, the amount of energy absorbed outside the passenger

compartment (e.g., in the front-end of the vehicle or road crash attenuators), the energy absorbing or energy concentrating characteristics of the contacted surfaces, and the energy absorbing ability of the organism. The more prominent technologies available to reduce severity of crashes are restraint use by vehicle occupants, reduced vehicle speeds, energy absorbing materials in the exterior perimeter and in the occupant compartments, removal of rigid roadside objects or placement of energy absorbing materials in front of them, improved skid resistance of roads, improved road definition by striping and reflectors, improved visibility of vehicles by lighting and reflectors, improved brakes on heavier vehicles and separation of heavier and lighter vehicles.

Since a crash on any given trip is unpredictable, restraints must be used every time a child is in a moving vehicle for the optimal benefit. For the youngest children, parents must purchase, rent or borrow a special restraint and buckle the restraint to the vehicle seat and the child in the restraint. Older children can use the seat belt that is standard equipment in most vehicles. Restraint use is a frequently required behavior that is generally resistent to change. Surveys of use of child restraints in 1974 found

that 93 percent of children less than 10 years old were not restrained (5).

Several experiments involving attempts to persuade parents to use child restraints have been reported. In 1976, in an urban obstetrics hospital, mothers with newborns were told that child restraints were available for purchase in the hospital gift shop. They were divided into three experimental groups and a control group. One group received literature on child restraint effectiveness, one group received the literature and a discussion by a person trained in persuasive techniques, and one group received literature and a free restraint. In comparison to the control group that received no information other than availability of restraints for sale, only the group that received free restraints were observed to be using them more in followup observations of use, about a 7-8 percentage point increase (6).

A controlled study in pediatric practices found some effect of counseling by the physician. The counseling included a prescription for a child restraint and demonstration by the physician as to its proper use. In return visits, observed restraint use increased by 23 percent in the first month, 72 percent in the second month,

but was only higher than a noncounseled control group by 9 and 12 percent at four and fifteen months respectively (7).

The full extent of application of these findings is unknown. Numerous hospitals and other organizations around the country have developed loaner or free restraint programs that have increased use substantially, up to 90 percent at hospital discharge in one state (8). Many such programs have been initiated or benefited from the "A First Ride, A Safe Ride" promotional activities of the American Academy of Pediatrics. How many of the restraint users would have purchased restraints in the absence of the loaner programs or use them regularly after hospital discharge is unknown as is the extent of physician counseling, but there is undoubtedly some net increase in child restraint use from such efforts.

A second approach has been the requirement by state law that restraints be used by children up to specified ages. Initiated in Tennessee in 1977 after effective lobbying by pediatricians and other concerned citizens, by 1985 all states had some type of law requiring child restraint use. The Tennessee law applied to children less than four years old transported by parents or legal guardians in vehicles owned by them, but exempted recreational vehicles of the truck or van type and trucks weighing more than a ton.

Observed restraint use by children less than four years old increased from 8 to 28 percent in the first three years of the law (9).

Studies of the effects of these laws on childrens' injuries have indicated reductions. Fatalities to children less than four years old in Tennessee declined about 50 percent from 1978 to 1983 in parallel with increases in citations by the police for nonuse of child restraints (10). Since restraint use did not increase enough to account for that much decrease in deaths, other factors were also reducing the death rate. A study of motor vehicle occupant injury and death to children in California before and after its 1983 law, compared to Texas before its law went in force, found about an 8 percent reduction in injuries in the first year, but no significant reduction in deaths (11). However, the statistical tests applied were of questionable power to test for changes in deaths in one year.

An analysis of the fifty state laws requiring child restraint use found that about 39 percent of the children 0-5 years old killed in the year preceding the laws were not covered by the enacted law because of age and other exemptions. The age limit is under 6 in five states, under 5 in 15 states, under 4 in 25 states, under 3 in one state, and under 2 in four states (12). It has also been observed

that child restraints are often not properly anchored. In 3447 observations of child restraints in vehicles in parking lots, 6 percent were not anchored to the seat belt and 75 percent were improperly anchored. Of 1648 restraints with a tether attachment, 68 percent were not attached and an additional 16 percent were not correctly attached (13).

In sum, child restraint education and laws have contributed to reductions in child injury, but even allowing for spillover effects to age groups not covered by the laws, these laws could not have produced all of the reductions in motor vehicle deaths noted in Table 1. One anomaly regarding child restraint use should also be noted. While adults have long been required to use seat belts on airplanes, infants are exempted. A study of aircraft crashes found that infants were about 7 times more likely than adults to die in aircraft crashes per numbers involved (14). Infant restraints used in cars can also be buckled into airplane seats.

From 1984 to the summer of 1986, required restraint use by older children and adults had been enacted into law in 27 U.S. states, but Massachusetts and Nebraska repealed their laws by public referendum in the 1986 election. The first major jurisdiction in the world to enact belt use legislation was Victoria, Australia following a decreased

death rate associated with required belt use on a major construction project. Deaths in Victoria declined about 10 percent in rural areas and 20 percent in urban areas compared to the expected rates based on trends in provinces without the law (15).

The results in states of the U.S. that have had laws in force more than a year indicate a similar experience. The first U.S. state to enact a belt use law, New York, experienced a 16 percent reduction in fatalities in the first year, but the reductions were less in other states -- 10 percent in Michigan, 6 percent in New Jersey, and 5 percent in Illinois (16). New York is the only state among these where citation for not using a seat belt is allowed without some other violation.

Although belt use increases substantially when the laws are first enacted, it subsequently declines to less than 50 percent (16). It is too early to estimate the long term effect of such laws. They were not in force during the period covered in Table 1 and could not have contributed to the noted reduction in death rates. If the Massachusetts and Nebraska repeal experience spreads, belt use laws may not be sustainable politically. The probability of laws in other states is also reduced.

In the absence of child restraint and belt use laws, use is very low, 7-15 percent, despite attempts to persuade people to use them. Carefully controlled experiments of the effects of advertising campaigns on belt use indicates no effect (17,18). Advertising and publicity in combination with a law does have an effect. In Australia, child restraint use increased about 15 percent in association with an advertising campaign regarding the child restraint law (19). In Elmira, New York, publicity regarding a crackdown by police on nonuse of seat belts resulted in 77 percent use (20). In California, where the law only allows citation for nonuse of belts if some other law is violated, publicity and special enforcement in one community increased belt use from 45 to 55 percent (21).

Increased restraint use is expected from the use of automatic restraints -- seat belts that automatically encircle front seat occupants or air bags that inflate when crash forces above a specified concentration are detected by sensor in the front end. After 17 years of on-again, off-again attempts at regulation, and a Supreme Court decision ruling the recision of the regulation as illegal, the U.S. Department of Transportation's rule that automatic restraints be phased in during the 1987-1990 model years is being implemented. The extent of the effectiveness of the

standard will depend on the technology used. While air bags work automatically, some of the designs for "automatic" seat belts allow them to be detached, defeating the automatic feature. Also, the Secretary of Transportation has ruled that the standard may be rescinded if states including two thirds of the population enact belt use laws having specified features. Many of the state laws do not measure up to the specified criteria and resolution of the issues involved remain in doubt. A few European manufacturers are installing driver-side air bags as standard equipment and one U.S. manufacturer offers them as an option on two models. Other manufacturers are reported to be gearing up to offer driver-side air bags. These will not protect children, but full front seat protection has been promised for the future by some manufacturers (22). Similar promises were made but unkept in the past (23).

The National Highway Traffic Safety Administration has crash tested selected car models into a solid barrier at 35 miles per hour since 1979 and published the results. These tests revealed up to five-fold differences in the accelerations on the head, chests and knees of test dummies (24). Some manufacturers have improved the energy absorbing capability of the front ends of their vehicles and the belt and seating systems as a result of these tests. Research

correlating the test results with death rates in particular vehicles have produced conflicting results. More research is needed, controlling for other factors that contribute to death rates, to assess the effects of these improvements.

At least part of the reductions in deaths to children in motor vehicles is the result of federal legislation and previous regulation. In 1966, the Congress enacted two federal statutes aimed at reducing motor vehicle deaths, the National Traffic and Motor Vehicle Safety Act (Public Law 89-563) and the Highway Safety Act (Public Law 89-564). The former provided authority to establish vehicle and equipment safety standards and the latter provided for federal assistance to the states.

The initial standards for 1968 and subsequent model cars (trucks were exempted from many until a decade later) included shoulder belts in outboard seating positions, energy absorbing steering assemblies, redundant braking systems, improved door latches to reduce ejection, interior padding, seat integrity, reduced glare in drivers' eyes, and side running lights, among others. Subsequent standards included hoodlatch and brake fluids in 1969, child seating systems and power operated windows in 1971, flammability of interior materials and retread tires in 1972, side door strength and roof crush resistence in 1973, one piece lap

and shoulder belts in 1974, rear end fuel system integrity and windshield zone intrusion in 1976, and high mounted brake lights in 1986. In addition, there were numerous amendments to earlier standards as a result of studies of effectiveness. Lack of compliance was a problem in earlier years but declined. Noncompliance across all standards for new cars tested during 1968-1971 ranged from 19 percent in 1969 to 11 percent in 1971. The range for the 1974-1978 models, when new, was 1-10 percent (25).

Estimates of the effects of these standards, based on comparison of fatalities involving vehicles in fatal crashes to which the standards did or did not apply, indicate approximately 15,000 fewer deaths per year in 1979-1982 than would have occurred without the standards. Both occupant deaths and nonoccupant deaths (struck by the vehicles) were reduced (26). A controversial study claimed that drivers with increased protection drove more riskily and killed more "pedestrians" (27), but the study included motorcyclists as "pedestrians", during a period when motorcycle registrations were doubling every five years due to cheap imports. Appropriate disaggregation of the data (28) as well as observation of driving behavior by drivers when belt use increases (29) indicates that the risky driving theory is wrong.

While much of the death reduction due to federal safety standards was realized prior to 1980, some of the reductions observed in the 1980s can be attributed to the continued junking of vehicles that did not meet the standards. To the author's knowledge, the effects of the standards on death reductions of children separated from adults have not been estimated.

Despite the federal standards for vehicle interiors, many, if not most, vehicles have protrusions such as knobs and tapered dashboards that concentrate energy exchanges with the faces, heads and chests of children in crashes and sudden braking (30). One study found that 12 percent of childrens' injuries in motor vehicles occurred in noncrash braking or swerving (31).

The 1986 and subsequent model cars are required by federal standard to have a new brake light mounted above the rear trunk. According to experiments in fleets where vehicles were randomly assigned to have such lights or to control groups, the extra brake light will reduce rear-end collisions while braking by about 50 percent (32).

Several federal standards applicable to school bus occupant injuries were adopted in 1977: maximum roof crush in a crash, joint body strength, strengthened seats and higher, padded seatbacks, and fuel system integrity (33).

Deaths to pupils that were school bus occupants in crashes declined from 60 in 1976 to 10 in 1983 (34). Since the vast majority of old buses were not likely to have been replaced during that period, all of the reduction in deaths cannot be credited to the standards. The extent that this reduction can be attributed to the changes in bus crash protection, before or in response to standards, is unknown, but the standards probably contributed to part of the reduction.

The effects on fatalities of federal funds awarded to the states for highway safety have been studied by comparing changes in fatalities among states according to their allocation of such funds. Those states that used federal funds for increased driver education in public schools had increased fatality rates while those states that allocated the funds to other projects had decreased fatality rates (35). Driver education in public schools has been found to increase the fatal crash involvement of 16-17 year old drivers because the trained drivers obtain licenses earlier than they would have without the school program (36). In Connecticut, when driver education was dropped from nine school districts following the elimination of state funding of the program, licensure and crashes of 16-17 year olds declined precipitously in those districts compared to districts that maintained the program with local funds

(37). The specific effect of the federal funding of state programs on children's deaths has not been estimated. Teenaged drivers kill children and adults as well as themselves when they crash. Federally funded programs, other than driver education, reduce deaths, presumably in all age groups.

In 1973, the Highway Safety Act authorized federal assistance for improvements at railroad crossings. The numbers of motor vehicle fatalities at railroad crossings declined from 1128 in 1974 to 542 in 1984, a decline of 52 percent, while potential exposures increased 4 percent (38). The proportion of children involved in these crashes has not been calculated.

A separate federal assistance program for highway safety is administered by the Federal Highway Administration in grants to the states for highway construction and safety improvements from the Highway Trust Fund. Although the effects of these projects in total have not been estimated, specific highway changes are associated with death reductions. Limited access roads have substantially lower death rates per mile than so-called feeder and arterial roads (39). However, such roads may result in increased miles travelled so that the net reduction in deaths, if any, is less than the per mile rates suggest.

Energy absorbing materials at sites where roadside objects concentrate energy when vehicles leave the road and hit them are known to reduce deaths (40). Research comparing sites where deaths or injuries resulted from crashes with fixed objects with sites that the vehicle passed without incident has specified the characteristics of sites with high risk (41). Approximately 25 percent of these deaths could be prevented by improvements on less than 8 percent of road sections. In Georgia, selective road striping based on this research resulted in a 20 percent reduction in deaths from that expected (42). The extent to which road improvements in other states is based on research as to high risk sites is unknown.

Attempts at speed reduction are mainly limited to law enforcement of speed limits. A National Research Council Committee estimated that the 55 mile per hour speed limit reduced deaths by 2000-4000 from what would have been expected in 1983 (39). Since the decline in death rates attributable to the reduced speed limit occurred in the 1970s, the declines in the 1980s can not be attributed to the law. However, the evidence indicates that a repeal of the law would result in increased deaths.

In the early 1970s, the National Highway Traffic Safety Administration proposed a standard that would place a limit on the top speed capability of vehicles, but the rule was not adopted. Most road vehicles are capable of speeds two to three times the 55 mile per hour speed limit and manufacturers continue to agressively advertise that capability. Radar detectors are sold to enable speeders to flaunt the law. A Maryland study found that 81 percent of large trucks and 40 percent of passenger cars had radar detectors (43).

Some trucking companies install tachometers in their trucks that include records of the speed. The extent of the penalties to errant drivers and the effect of this technology on controlling speeds needs investigation.

Tractor-trailer and other truck combinations are involved in 9.9 percent of fatalities in 1983 although they were only 0.7 percent of registered vehicles. Deaths to car and truck occupants in collisions of lighter vehicles with these heavy trucks increased from 4600 in 1976 to 5700 in 1983 (34).

Truckers have been found to disconnect front tractor brakes in the mistaken belief that control of the vehicle is increased. Studies dating from 1975 have indicated that removal of front axle brakes on tractor-trailer trucks increased stopping distances 20 to 35 percent with no

improvement in vehicle control. Nearly 31 percent of trucks inspected by the Bureau of Motor Carrier Safety (BMCS) in 1983 were removed from service because of safety defects, two-thirds of these had inoperative or defective brakes. Yet BMCS reduced its inspection activities by 23 percent from 1983 to 1984. It allocated $6.5 million to 17 states to train state employees to conduct inspections (44).

Technology to prevent cars from underriding trucks, shearing off the tops of the cars, and sometimes the heads of occupants, has been developed but largely unused. Current standards require an underride guard on the rear of large trucks, but these have been shown in crash tests to be ineffective (45). Nighttime car into truck crashes were reduced about 18 percent in one experiment by placing reflector tape around the outline of the truck trailor (46). One strategy that is also largely unused would require heavy trucks to use only certain roads or restrict use on certain roads to the least hazardous times of day. The New Jersey Turnpike from New Brunswick, Jersey to New York has a separate channel for trucks and buses.

A strategy to increase vehicle conspicuity is to require use of lights in daytime. This requirement has been in effect for motorcycles in some states for years, and lights on new motorcycles are required to have lights that are lit

automatically when the engine is in operation. Visibility of vehicles has been found experimentally to increase when headlamps are in use. In on-road use, 2000 cars, trucks and vans with an inexpensive relay to turn on front parking lights and rear lights at ignition were involved in 22 percent fewer collisions than comparable vehicles without the equipment (47).

At signalized intersections, the length of the yellow phase between green and red, relative to road design criteria, is strongly correlated to crash rates. Intersections with yellow phase 10 percent less than engineering design standards had about 6 times the crash rates of those intersections with a yellow phase 10 percent or more longer than design standards (48).

A new vehicle that has increased children's deaths and injuries recently is the so-called "all-terrain vehicle". These are motorized vehicles that, in the three-wheeled version, look like a large tricycle with balloon tires, but are capable of speeds of 40 or more miles per hour. Usually operated off roads, these vehicles were advertised showing children as operators. Injuries associated with "all-terrain vehicles", estimated from the emergency room surveillance system of the Consumer Product Safety Commission, increased from 8000 in 1982 to more than 60,000

in 1984. About 20 percent of these injuries occurred to children less than 12 years old (49).

This experience follows earlier increases from unlicensed motorized vehicles. Children less than 14 were involved in 21 percent of 13,361 snowmobile injuries in 1977 and 51 percent of injuries from unlicensed motor scooters and minibikes --small motorcycles capable of speeds of 50 miles per hour (50).

Pedestrians. Approximately half of children killed by motor vehicles are pedestrians. Less research has been done on pedestrian injuries than on occupant injuries. Children as young as three to four years old have been observed sufficiently removed from adults and close enough to moving vehicles such that a quick dart toward the vehicles could not be prevented. No significant difference in cautionary behavior was observed by age up to age 8. Children have more difficulty than adults in locating the direction of sounds and movement, as well as discerning the difference between right and left (51).

Attempts to educate children and drivers regarding vehicle direction, movement and appropriate behavior has mixed results. Some research indicates that children acquire and retain skills in street behavior easily (52), but other studies are more cautious. After training using model cars

and roads in one study, less than half the children remembered to look behind at intersections for turning cars and half the 6 year olds and 25 percent of 9 year olds did not remember to stay in the crosswalk. Signs showing a running child, to warn drivers in areas where there were children, were interpreted by some of the children as the place one could safely run across the street (53). The curb drill, "look to the left and look to the right" is interpreted by some children a a magic incantation that will protect them (53).

Among children 4 to 7 years old, darting out into traffic is the behavior associated with about two-thirds of pedestrian injuries. A film and television spot program, using a character called "Willy Whistle", has been developed concentrating on getting children to stop and look for vehicles when they come to a curb or the edge of a parked vehicle. The films and spots were distributed to schools, theaters and television stations in three cities. A 20 to 30 percent reduction in child pedestrian injuries involving dartout was observed in the cities where the materials were distributed (54).

Identification of high risk sites for pedestrian injury and the associated movements of the pedestrians and vehicles has also led to experimentation with site modifications to

reduce risk. Depending on the actions of pedestrians and drivers at given sites, countermeasures included preventive markings, median barriers, set back of cross walks, midblock crosswalks, barriers at parking meter posts, stop line relocations, vendor warning signs, and bus stop relocations. With the exception of preventive markings and vendor warning signs, each of these modifications was associated with changes in driver or pedestrian actions believed to reduce risk (55). More work of this type, including measurement of actual changes in injury rates, is needed.

Law enforcement of child behavior has apparently not been studied, but citation of adults for illegal street-crossing behavior has no discernable effect on the behavior or pedestrian injuries (56). One piece of the legislation to reduce energy consumption increased child pedestrian injuries. The right-turn-on-red laws were compared among states as they were adopted and an increase of more than 30 percent in injuries to child pedestrians was associated with the adoption of the law (57).

A detailed review of pedestrian injuries led one author to estimate that one-third of serious pedestrian injuries could be reduced by changes in vehicle design. Hard surfaces, sometimes tapered to a point like an arrow or lance on hood fronts and corners, are not uncommon on the

front ends of vehicles. These designs serve no function, unless one considers them somehow more esthetic than flat, energy-absorbing surfaces. Lower bumpers in combination with energy absorption in hood and windshield areas, that pedestrians tend to rotate into when struck, are the most efficacious designs (58).

Bicycles. Child bicyclists are most seriously injured in collisions with motor vehicles. About 1 in 4 injuries involving bicycle-motor vehicle collisions result in hospital admission of the bicyclist compared to 1 in 20 bicycle injuries not involving motor vehicles (59). Almost 40 percent of fatalities occur when the driver runs upon a bicyclist from the rear and 27 percent occur from bicycles darting out (59). Brain injury has been found the primary cause of death in about three-quarters of bicyclists' deaths (59).

Use of helmets by bicyclists is suggested as one strategy to reduce severe consequences but no study of the effects of currently manufactured helmets in use has established their adequacy. Paths separate from the road may encourage children to use their bicycles away from traffic, a strategy reported to have had some success in Scandinavia. Enforcement of traffic laws for bicyclists is probably less systematic than that for motor vehicle drivers. In several

Minnesota counties, bicycle injuries were reduced in correlation with enforcement that included a request to parents the the child attend a Bike Violator's Seminar (59).

Changes in the front ends of motor vehicles from energy concentrating points and edges to energy absorption would probably reduce severity of bicyclists injuries in addition to those to pedestrians.

Heat and Smoke. Most deaths to children from heat energy and accompanying smoke occur in housefires while major nonfatal injuries occur from scalds and contact with hot surfaces. The leading source of ignition in housefires (30 to 45 percent) is the cigarette, usually dropped in a bed, couch or chair and left to smolder, often as the occupants of the household sleep (60).

The reductions in fire-related death rates are associated with great increases in the installation of smoke detectors in residences. There has been little change in the numbers of housefires (61). According to national random sample surveys, smoke detectors in households increased from 22 percent in 1977 to 46 percent in 1980 to 67 percent in 1982 (62).

Smoke detectors require much less action by the user to be effective than restraint use in cars, probably a strong factor in its more frequent use in response to persuasion.

An experiment in a pediatric practice, in which an experimental group received counseling regarding the importance of installing a smoke detector, correctly installed detectors increased from 46 percent to 65 percent with no change in a control group (63).

The city of Baltimore, MD gave away 3720 smoke detectors to those who asked for them in 1982. In a study of 231 randomly selected recipients, selected from among those that received the smoke detectors and had to install them without assistance, 92 percent of the detectors were found installed and 88 percent were operating correctly 4 to 9 months later. Furthermore, the recipients were highly concentrated in areas of the city with the greatest fire injury rates (64).

Legislation has also contributed to smoke detector use and reduced deaths where it has been attempted. In Montgomery County, Maryland, where smoke detectors are required by law in all residences, the number of working detectors is greater and the number of residences without detectors is less than in nearby Fairfax County, Virginia without such a law. From the 6-year period before the law to the 6-year period afterward, fire deaths in Montgomery County declined more rapidly than in Fairfax County (65).

Different degrees of success have been reported from attempts to increase community awareness of a variety of means to prevent fires and heat-related injury. The Missouri Division of Health identified a six county area that had fire deaths two to five times that of other areas of the state. With funds from the U.S. Public Health Service, a health educator and three field representatives developed contacts with a wide variety of governmental and civic groups, as well as news media. Data were gathered on the circumstances of burn injuries and the populations involved. A Burn Prevention Demonstration Unit was developed and presentations were given to community and school groups. From the three-year period before the project to the three year period afterward, fire related deaths decreased some 43 percent (66). Since an area with a high rate was chosen for intervention, some of the reduction could have occurred from so-called regression to the mean, that is, areas with rates less or greater than average during a given period tend to trend toward the average in subsequent periods. Nevertheless, it is likely that the program contributed to at least part of the reduction.

In Massachusetts, two communities received an education program aimed at burn prevention, delivered in news media, community groups and the schools. In comparison to control

communities, self-reported knowledge of preventive actions increased, but only 13 percent of respondents said they applied the knowledge at the moment of risk. No detectable decrease in burns could be found (67).

Specific information on the source of burns is important in targeting control efforts. In Denmark, a surgeon identified a coffee filtering device as the source of 60 percent of burns associated with spilled coffee. A campaign was initiated that included redesign and marketing of a new design and public information on dealing with the extant devices. The coffee scalds were reduced by two-thirds (60).

State and federal regulation of flammability of fabrics has contributed to death reductions from that source. The Flammable Fabrics Act was enacted in 1953 and amended in 1967 to cover a wider range of fabrics. Deaths associated with clothing ignition decreased by 71 to 82 percent from 1968 to 1979. Among children, the reduction was even greater, partly due to changes in clothing styles such as reductions in use of frilly dresses (2), and partly due to the fabric standards, particularly for childrens' sleepware (68).

Several potential targets for regulation to reduce burn injuries have been identified. Residential sprinkler systems would undoubtedly reduce deaths from housefires (69). Most brands of cigarettes have design characteristics and additives that promote continued burning for up to forty minutes when dropped (60). These could be required to be modified, but no federal agency has the authority to do so. The Consumer Product Safety Commission is specifically prohibited from regulating cigarettes.

Burns from over-heated tap water are a major source of childrens' burns. Standards for maximum temperatures for new water heaters could be set and utility companies could be required to reduce the temperature on extant water heaters during routine meter reading (70). Insulation of heating registers, stoves and fire places could be increased. Manufacture and sale of fireworks with particular heat, diffusion of heated particles, or explosive characteristics could be banned.

Drowning. Children drown in a variety of collections of water including bathtubs, buckets, swimming pools, lakes, rivers, floodwaters and, rarely, oceans. Although studies in a few states and local communities have documented the water collections involved, no national estimates are available

(71). There is undoubtedly local and regional variation related to access to types of water collections and climatic conditions that influence use.

Teaching children as young as toddlers to swim has been advocated in some circles, but its effects on drowning in the aggregate are unknown. One study found that toddlers who had been trained to swim less often required retrieval from toddler pools (72). This does not take into consideration the extent to which swimming lessons increases the amount of swimming and potentially increases drowning in the aggregate. Research analogous to that noted for driver education is needed to resolve the question.

Drownings associated with children wandering into unsupervised swimming pools are substantially less in areas that require fences and childproof gates around pools. The annual pool-fatality rate in Honolulu, where pool fencing is required, was found to be about one third that in Brisbane, Australia, which had a similar climate and pool-to-household ratio, but no required pool fencing (73).

Poisoning. Poisoning deaths in children have become increasingly rare after the adoption of containers for certain drugs and household chemicals that are resistant to being opened by children. Child poisoning deaths from aspirin declined 80 percent from 1965 to 1975 when

manufacturers voluntarily adopted container caps difficult for children to remove (74). By authority of the Poison Prevention Packaging Act of 1970, standards for specific products were promulgated from 1972 to 1980. Reported ingestions of the regulated products by children less than 5 years old, measured from the year that a given product was regulated to 1983, declined from 40 to 90 percent (75). There were complaints from adults who had difficulty opening "childproof caps" initially, but these seem to have subsided. No literature was found on the extent of this problem and the modifications, if any, that may have reduced it. Several drugs and household solvents, corrosives and caustics continue to result in a child hospitalization rate of 5 to 12 per 100,000 children per year for each category of product (76).

Community poisoning prevention efforts, including community outreach seminars, school curriculum seminars, retail outreach efforts, distribution of educational materials, and publicity in mass media were associated with declines in emergency room visits for poisonings (77). Using Maternal and Child Health block grant funds as well as state and local funds, a variety of poison prevention efforts have been undertaken around the country (78). Apparently no

systematic evaluation of the effects of specific efforts has been done.

Other Child Injury Prevention. Efforts to prevent other types of injuries to children have included programs with general themes, such as home injury prevention, and specifically targeted programs based on surveillance of injuries and their circumstances. In general, the more specifically targeted approaches that include technology that is simple to use or protective without action of the users are the more successful.

In an attempt to reduce home injuries involving ten categories of household items, parents visiting a prepaid health plan with their children were given information on keeping the presumed hazardous items away from children. In a followup telephone call, parents claimed to have removed many of the items from childrens' access. In a home visit to these families and control families who had received no information, however, there was no difference between the two groups of families in the extent of childrens' access to the presumed hazardous items (79).

Falls of infants from elevated surfaces (tables, chairs, beds) were apparently reduced by a combination of messages to parents. The parents were given written material about childrens' falls and were counseled about them by the

pediatrician. Signs reminding parents of the messages were placed above the examining table where they could be seen in subsequent visits. Falls among the infants in the group receiving the messages during the subsequent year were about 10 percent compared to 17 percent among a comparison group that did not receive the messages (80).

Some organizations with responsibility for childrens' health have had significant successes. Although only 12 state health departments had any injury prevention programs in 1981 (78), the reports from some are encouraging. The New York State Health Department has been active in initiating programs directed toward specific injuries, such as those on playgrounds where a 35-50 reduction in hazards was observed (81). Identification of numerous hazards based on cases found by the department have been reported to the state Product Safety Commission and the federal Consumer Product Safety Commission resulting in voluntary recall of products, mandatory recall in some cases, and regulations for modifications (82,83).

Using federal Maternal and Child Health grants and state funds, the Massachusetts Department of Health has developed a multi-pronged child injury prevention effort including coding of child hospitalizations and 25 percent of emergency visits, coordinated efforts among pediatricians for

systematic counseling of parents about hazards, and a review of state and federal law that can be used for injury prevention (84). A pilot project that employed city health inspectors to review hazards with parents resulted in more than a 50 percent reduction in hazards for which codes existed (85). A state law enacted primarily for energy conservation and esthetics -- required deposits on beverage containers -- was associated with a 60 percent reduction in glass-related lacerations (86).

The Indian Health Service organized local Community Injury Control Committees in its service units, mainly on reservations, in 1982. Most of the initial efforts were directed toward education of the population in a variety of hazards. Although childrens' injuries were not studied separately, hospitalization per population for fall injuries in 54 service units declined 35 percent from 1980 to 1984. The declines across service units were correlated significantly with proportion of the population trained in general safety, recreational safety and first aid (87). A more specifically targeted effort based on surveillance of severe injuries is being initiated.

Federal regulations for refrigerators, cribs and state required warning labels for plastic bags have been studied in relation to child suffocation and strangulation. Declines

in death rates from refrigerator entrapment and suffocation by plastic bags were found, but not in strangulation from wedging in cribs (88).

A local health department effort perhaps best illustrates the effect of the combination of good epidemiology, choice of a simple, effective control strategy and employment of a mixture of persuasion and regulation in program effort. In New York City, epidemiologists noted that childrens' deaths from falls were much greater than would be expected from national population data. Investigation of 201 such deaths in 1965-1969 revealed that 61 percent of the fatal falls to children less than 15 years old and 85 percent of those to children less than five years old occurred to children that crawled out of windows, 96 percent in the three of the five Burroughs of the city -- Bronx, Brooklyn, and Manhatten (89). A barrier that could be placed over the windows, preventing children from crawling out, was the technical approach identified as most feasible. A campaign was launched in high-risk neighborhoods to persuade the parents or landlords to install the barriers (90). Eventually, the Health Department required landlords to install the barriers when requested by tenants. In association with these efforts, childrens deaths in falls from windows declined from 30 to 60 per year in the mid 1960s to 4 in 1980 (91).

Subsequently, as families moved and children were born in new families, the fatal falls increased. In July, 1986, the city changed the regulation to require barriers in windows in buildings where there were children less than 11 years old, without the necessity of parental request.

Costs

The costs of injury to the injured, their families, and society, and the costs to individuals, governments, and private organization for injury control are not easily measured. Costs of funerals, hospitalizations, emergency and rehabilitative medical services and treatment, and who pays these costs, can be estimated from reasonable samples, but the psychic and social costs to the injured and their families and friends are not measurable in monetary terms. Estimates of costs of lost productivity vary widely depending on assumptions of the future of the economy and discount rates.

The National Highway Traffic Safety Administration (NHTSA) estimated that the societal costs of motor vehicle accidents in 1980 were $57.2 billion, including $7.5 billion in costs to the federal government in public assistance programs and other expenditures, and revenue losses. Cost to

state governments were approximately $3.4 billions in state shares of public assistance programs and lost revenues (92). Since motor vehicle injuries are about half the total unintentional injury problem, the total costs were about twice those amounts.

A crude estimate of the cost of all injuries can be made by applying the NHTSA estimates to all injuries, adjusting for inflation. Excluding property damage costs, NHTSA estimated a cost of $36.2 billions in costs for motor vehicle injuries in 1980. The cost per death was $710,117. Adjusted for inflation using the implicit price deflator for GNP (93), that is $1,162,294 per death in 1984 dollars, including about $241,000 in governmental expenditures and lost revenues. Note that this is an estimate of the cost of all injuries per death, not just the "value of a life lost." Obviously, estimate of the value of a life lost in this calculation includes only lost productivity and direct costs, not the incalculable total value of a life or the pain and suffering of injury. Applying this cost to all injuries is crude because the ratio of nonfatal injuries to deaths is lower for some, such as drownings, but higher for others, such as falls. The adjustment for inflation is conservative because hospital and medical treatment costs have increased far more rapidly than other prices in the economy.

Table 2 presents the crude estimates in total costs and costs to governments in various types of assistance and lost revenues. These costs were estimated by multiplying the total costs of all injuries per death times the number of deaths in a given year in 1984 dollars.

These estimates suggest societal costs in the range of $108 to $123 billion for unintentional injuries each year from 1980 through 1984. Federal government expenditures and lost revenues ranged from $22 to $26 billions and state governments lost about $10 to $12 billions per year. Injuries to children less than 15 years old cost society on the order of $9 to $11 billion per year with federal and state governments loosing about $2 billion and $1 billion per year respectively.

Government Programs. Costs of government funding of research and control programs can be estimated, but estimates for control of childrens' injuries separate from those to the older population are apparently not possible. The author surveyed 20 federal government agencies as to their recent budgets for child injury prevention. Of those that had programs, most failed to indicate costs because they could not distinguish amounts applied to childrens' injuries separate from the general programs. As noted in the literature review, substantial reductions in injury to the

Table 2. Estimated Total Costs and Governmental Costs of Unintentional Injuries in Billions of 1984 Dollars.

Year	Deaths	Total Cost	Federal Government	State Governments
1980	105,718	122.9	25.5	11.9
1981	100,704	117.0	24.3	11.3
1982	94,082	109.3	22.7	10.6
1983	92,488	107.5	22.3	10.4
1984	92,911	108.0	22.4	10.5
Children Less Than 15 Years Old				
1980	9,703	11.3	2.3	1.1
1981	8,996	10.5	2.1	1.0
1982	8,612	10.0	2.1	1.0
1983	8,320	9.7	2.0	0.9
1984	7,850	9.1	1.9	0.9

population generally have been associated with several of these programs, but the effect on childrens' injuries in particular has not been estimated in most cases.

The Department of Agriculture has no program for injury control on farms other than assistance "in the designation and recognition of Farm Safety Week, the purpose of which is to draw greater attention to the need for safety awareness." It is very doubtful that this has any effect.

The National Bureau of Standards of the Department of Commerce has no current programs related specifically to child injury prevention. Its Center for Fire Research has had important impact on fire fighting equipment in the past and recent work on smoke detectors and sprinkler systems as well as burn rates of certain materials may have been a factor in the increased adoption of that technology. The Bureau has in the past done work on flammable fabrics, playground equipment and surfaces, toys, hot surfaces, Christmas tree lights, sharp edges, pointed objects and swimming pool slides, under contract to the Consumer Product Safety Commission.

The Department of Defense has several programs for dependent children of armed services personnel, including school crossing guards, school programs for safety and fire prevention, required fences around swimming pools, and required child restraint use in transportation of children on DoD installations.

Several agencies within the Department of Health and Human Services devote effort to injury control. The Administration for Children, Youth and Families provides safety promotion materials to Head Start Programs. Its primary focus in injury control is addressed to intentional injuries by reason of its mandate to provide information and technical assistance to the states regarding child abuse and neglect.

The Centers for Disease Control (CDC) awarded small contracts to states, private organizations and academic institutions to develop injury control strategies during the 1970s and early 1980s. The total amount expended in this effort from 1975 through 1985 was $765,000. In 1986, $300,000 was allocated to injury control and a Division of Injury Epidemiology and Control was organized. The recent allocation of $10 million per year to CDC for injury research through 1990 (Public Law 99-649) will result in a quantum jump in research.

The Food and Drug Administration has conducted poison prevention efforts by means of educational materials and warning label requirements on both prescription and over-the-counter drugs.

The Indian Health Service established Community Injury Control Committees in a majority of service units in 1982-83. Environmental health officers spend part of their time in injury control activities, but the proportion devoted to childrens' injuries is not quantifiable. An injury surveillance system is being pilot tested in several service units.

The National Institute for Child Health and Human Development (NICHD) supported a total of $40,000 in research on injuries from 1981 through 1985, out of an annual budget ranging from $223.5 million to $313.0 million during these years. The Senate Appropriations Committee in February, 1986 requested a report from NICHD regarding its activities in the area, in view of the fact that injury is the leading cause of death to children aged one or older. The report is being prepared. NICHD has made a preliminary allocation of $326,000 for child injury research from fiscal 1986 funds.

The Department of Housing and Urban Development conducts education campaigns regarding the hazards of lead in chipped paint and plaster that children tend to eat, and issues regulations regarding the elimination of lead from public subsidized housing. While subclinical lead poisoning may be considered a disease rather than an injury, the consequences in impaired reaction time, mental retardation and various

behavioral changes (94) are factors that likely place children with the condition at greater risk of injury.

The Department of Transportation has responsibility for injury control in various modes of transportation. The Coast Guard sets standards for boats and encourages use of flotation devices by children and adults on recreational boats. It offers a one lesson "Young People's Boating Course" for 11-15 year olds and a presentation called "Water 'n Kids" regarding the safety of 5-8 year olds.

The Federal Aviation Administration at one time did not allow child restraints designed for cars to be used in commercial aircraft. It now allows such use but does not require it.

The Federal Highway Administration (FHWA) administers grants to the states for road construction and site modification to reduce crash incidence and severity. These are aimed at protection of the population generally, including children, but no special attention to highway hazards to children are considered. Less than 1 percent of the $58 billion administered by FHWA in 1981-1985 was expended specifically for safety-related grants and research. New highway construction and road improvements are supposed to meet safety standards, but it is not possible to separate the safety-related from other expenditures.

The laws administered by the National Highway Traffic Safety Administration and their effect on fatality rates were discussed in the literature review. The Surface Transportation Assistance Act of 1978 required that two percent of highway safety grants to the states be allocated to increasing use of seat belts and child restraints. The requirement has since been increased to eight percent in fiscal 1985 and 1986. In fiscal year 1985, this requirement resulted in $15.8 million of the grants to states being obligated to restraint use programs, of which $9.3 million was dedicated to child restraint use. These funds were used for education, public media campaigns, and child restraint loaner programs, as well as use surveys and administration of the programs. During fiscal years 1979 through 1985, $915.2 million was allocated to state and community programs as follows: 22.7% to alcohol countermeasures, 40.2% to police traffic services, 7.1% to emergency medical services, 5% to traffic records, 5.3% to restraint use programs, 2.1% to school bus driver training, 0.9% to motorcycle safety, 1.5% to pedestrian safety, 9.0% to planning and administration and 6.3% to "other" (95). NHTSA has also supported some research and demonstration projects regarding child pedestrian injuries, such as the "Willy Whistle" program mentioned in the literature review.

The Consumer Product Safety Commission (CPSC) is authorized by the Consumer Product Safety Act, and laws pertaining to specific products (hazardous substances, flammable fabrics, packaging of poisons, and refrigerators) to reduce injury to children and adults by gathering information on consumer products involved in injury, development of mandatory and voluntary standards, and recall of hazardous products. The Commission gathers data through a network of emergency room reports of injuries related to products as well as special investigations related to complaints. During fiscal 1985, 277 toys and children's products were tested and failure to comply with CPSC standards were found in 58% of cases. These were products for which the Commission had reason to suspect problems and does not indicate that degree of hazard in children's products generally.

The National Transportation Safety Board (NTSB) investigates injury incidents and issues reports including recommendations to regulatory agencies. It has been involved in the encouragement of child restraint legislation, the use of child restraints on aircraft, and the inadequacy of current seat belts in rear seats. The latter report was criticized by safety experts because of concern that the publicity surrounding it would discourage seat belt use.

However, NTSB notes that automaker announcements that shoulder belts would be placed in rear seats were prompted by the study. NTSB's budget was less than $22 million per year from 1981-1986 with about 1 percent of that amount devoted exclusively to children's injuries.

Due to budget cuts, inflation, and anti-regulation ideology, the efforts of the agencies with primary responsibility for child injury prevention have been eroded in the 1980s. The Consumer Product Safety Commission's budget was reduced from $43 million in 1980 to $34 million estimated for 1986. Adjusted for inflation, that is a 40 percent reduction. As a result, the Commission's survey of emergency rooms has been reduced to the point that estimates of the numbers of injuries related to particular products are of questionable reliability. The emergency room surveillance system was originally planned for 119 hospitals but now surveys only 62. As a result of the small sample, the confidence interval on products with an average injury incidence of 10,000 per year varies 30-40 percent from the average.

Adjusted for inflation, the National Highway Traffic Safety Administration estimated budget in 1986 ($290 million) is 19 percent less than 1980, although it was down by more than 40 percent from 1980 to 1983. Some of the

budget was expended in anti-regulatory activity, such as the rescinding of requirements for occupant protection that was overruled by the Supreme Court.

Research. The National Research Council/Institute of Medicine Committee on Trauma Research recently reviewed federal support of research on injuries relative to other leading causes of death -- heart disease and cancer. In its report, Injury In America: A Continuing Public Health Problem, the Committee noted that injury accounted for substantially more productive years of life lost than either of the other two major killers, but only $112 million in federal funds was spent for injury research in the 1983 fiscal year compared to $998 million for cancer research and $624 million for cardiovascular disease research (96). Although accounting of private funding for research was not done, it should be noted that private foundations spend substantial amounts for cancer and heart disease research, but little on injury research.

In response to the National Research Council/Institute of Medicine report, the Congress appropriated $10 million to the Centers for Disease Control (CDC) in 1986 to be used for injury control research. The first grants will be awarded in early 1987. Legislation to continue the funding at that level through 1990 has been enacted. CDC is cooperating with

the National Highway Traffic Safety Administration and the Consumer Product Safety Commission (CPSC) in the sharing of data and to prevent overlap in effort. CDC may use some of their funds to add to the information obtained by CPSC but their funds are inadequate to increase the CPSC sample to a more statistically reliable size.

The Epidemiologic Model

Injury in America lays out an extensive agenda for research on injuries. The model suggested for injury research and prevention is the epidemiologic model. Injuries are analogous to acute infectious diseases. Such diseases have been characterized by epidemiologists as the interaction of infectious biologic "agents" (bacteria, viruses, parasites) with "host" individuals. Often the agent is conveyed to the host by some animate carrier, such as a mosquito or another human being, called a "vector", or is conveyed by an inanimate carrier, such as water, called a "vehicle". Individuals who have not developed resistance become infected. Successful control of many infectious diseases that historically plagued children has been based on agent control, vehicle or vector control, or increasing resistence of the host. If the agents, vehicles or vectors,

and host factors that contribute to children's injuries are sufficiently identified and modified, control of children's injuries can be accomplished.

The agent of injury is physical energy at concentrations outside the range of human resilience. The forms of energy are mechanical, chemical, electrical, heat, and ionizing radiation. The major vehicles of energy damage to children in the U.S. are predominately motor vehicles, cigarettes (the major cause of housefires), water (in drownings) and gravity (in falls). In the case of asphyxiation, including drowning and smoke-related, it is too little energy produced by oxidation, rather than too much, that results in injury. To prevent injury, one must identify the agents and vehicles that are causing particular subsets of injuries and find a strategy that prevents or reduces the interaction of the agent with the host (97).

Traditionally, injury prevention was called "accident prevention" and focused on the behavior of the injured person or others in proximity that increased the risk of injury. Since many accidents are not injurious and behavior is often more resistant to change than agents or vehicles, the accident prevention approach, focused on behavior change, had very limited success (98).

Factors and Phases. Modern injury epidemiology focuses on the full range of factors in terms of what happened before the injury, what happened at the time of the injury, and what happened afterward that could have prevented the incidence or reduced severity. Intervention to reduce injury severity may focus on any combination of the factors at any phase.

This model is summarized in a matrix as follows:

	Factors		
Phases	Human	Vehicle	Environment
Pre-event	1	2	3
Event	4	5	6
Post-event	7	8	9

Consider injuries to child pedestrians. Pre-event, human factors are the behaviors and human characteristics that increase the probability of exposure to damaging energy, such as children playing in the vicinity of motor vehicle traffic. Pre-event, vehicle factors include the braking capacity and condition of brakes on motor vehicles. Pre-

event, environmental factors include parked vehicles or other objects that reduce drivers visual perception of children. Event-human factors include conditions of the children that increase the damage when impacted, such as hemophilia. Event-vehicle factors include sharp points and edges that concentrate energy at the point of impact, and raised bumpers that result in impacts to heads and chests rather than less vital legs. Event-environmental factors include hard road surfaces and other objects that a child pedestrian contacts in rebound from the impact and road and street designs that increase exposure to vehicles. Post-event, human factors include first-aid abilities of persons in the vicinity. Post-event, vehicle factors refer to property damage which is irrelevant to the child's injury. Post-event, environmental factors include the rapidity of response of the emergency medical system.

Viewed from this perspective, the behavioral factors that contributed to the injury are only a small part of the factors that could potentially be modified to reduce injury or severity. As was noted in the literature review, focus on factors other than "accident prevention" has been remarkably successful in reducing certain types of children's injuries.

Surveillance. Identification of interventions to effectively and efficiently reduce childhood injuries depends on research into the clustering of homogeneous subsets in space and time relative to specifically identified factors and phases of the injuries. This type of research is called surveillance.

Again using the example of child pedestrian injuries, surveillance research would specify the types of streets, roads or driveways on which the injuries most frequently occur, the time of day and day of week, what the children were doing at the time, the vehicles most frequently involved, the condition of the vehicles, the surfaces on the vehicle or in the environment that concentrated the energy exchanges to the children, the actions and conditions of the drivers, the post-injury actions to provide first aid to children at the scene, and the emergency medical response, and treatment and rehabilation of those that survive.

There are very few children's injuries that have undergone surveillance research in that degree of detail. In some instances, enough is known to select effective and efficient countermeasures, but too often countermeasures are employed without adequate surveillance.

Identifying Technical Countermeasures. Haddon (99) identified ten logically distinct categories of countermeasures that are applicable to hazards in general, biological or physical. These are:

1. Prevent the creation of the hazard in the first place.
2. Reduce the amount of the hazard brought into being.
3. Prevent the release of the hazard that already exists.
4. Modify the rate or spatial distribution of release of the hazard from its source.
5. Separate, in time or space, the hazard and that which is to be protected.
6. Separate the hazard and that which is to be protected by interposition of a material barrier.
7. Modify relevent basic qualities of the hazard.
8. Make that which is to be protected more resistant to damage from the hazard.
9. Begin to counter the damage already done by the hazard.
10. Stabilize, repair, and rehabilitate the object of the damage.

All of these may not be applicable to every hazard, but systematic review of each may result in identification of one or more countermeasures that is more effective or efficient than those traditionally accepted. Consider

examples of those that might be applied to children's drownings, identified by Haddon's numbering system:

1. Prohibit private, unsupervised swimming pools.

2. Reduce the number or permitted depth of private, unsupervised swimming pools.

3. Teach all children to swim.

4. Place sensors in dams and levees to signal need for release of waters at a controlled rate.

5. Place playgrounds at a distance from streams or reroute streams away from playgrounds.

6. Place unscalable fences and locked gates around swimming pools.

7. Not applicable. Water is not modifiable.

8. Require children to exercise to increase lung capacity.

9. Place underwater lights in pools.

10. Provide rehabilitation services to children with brain damage from anoxia.

These are only examples. Based on this conceptualization, long lists of options for a wide variety of injuries have been noted by various authors (100-105).

This technical options analysis does not take into account need, feasibility, or relative effectiveness. Clearly without adequate research, adoption of any one of

these options might be unneeded or ineffective. If no children are drowning in streams, options relevant to such bodies of water are unneeded. If children who drown know how to swim, training in swimming would be ineffective. Furthermore, without adequate research on the effect of such training, there is no guarantee that the training will not increase the amount of swimming, and associated drowning. Therefore, surveillance research is necessary to identify need in specific populations and research on the effectiveness of a given option is necessary before widespread adoption.

Implementation Strategies. Technical approaches can be implemented in one or more of three ways: 1. Change the behavior of the hosts or other persons (parents, teachers, coaches, drivers, etc.). 2. Require behavior change of the hosts or other persons in proximity to hazards by law or administrative rule. 3. Provide automatic protection by modifying the agents and vehicles of injury (106). The first two require action by millions of people while the third requires action by manufacturers and processors of hazardous energy and its carriers. In general, as was illustrated in the literature review, legal or administratively required behavior change is usually more successful than education or persuasion aimed at behavior change, and modification of

agents and vehicles is usually the most successful strategy. That is not to say that a legal or regulatory strategy is available or can be developed for all hazards. Several factors contribute to the relative success of each of these approaches.

The effect of education or persuasion strategies is largely dependent on the frequency of the behavior and whether or not the behavior change increases exposure to hazards. Generally, the more frequently people must act to protect themselves or children, the greater the difficulty in educating or persuading them to do so.

The effect of laws and administrative rules is dependent to some degree on frequency of the required behavior. Also important is the public observability of the behavior, which affects the probability of imposition of sanctions, and the extent of augmentation of enforcement by the community rather than sole dependence on police enforcement.

For automatic protection to be successful, the manufacturers and producers of potential hazards must be aware of and use technical strategies to reduce the hazardous characteristics of the agents and vehicles. This may occur based on in-house expertise or may be accomplished by governmental regulation. If governmental regulations are necessary, the regulators must have expertise in the

characteristics of agents and vehicles that are hazardous and must have the political support to impose and maintain appropriate standards.

Regulatory action is not immune to unintended consequences that can undermine the effectiveness of regulatory agencies. For example, some manufacturers responded to the Consumer Product Safety Commission's rule on flammability of children's sleepware by using an alleged carcinogen as a flame retardant. While the rule required reduced flammability, a performance rather than a design standard (i.e., it did not specify the technology to be used), the accompanying publicity and recall of the products treated with the suspect retardant perhaps undermined the agencies effectiveness for a time.

The Federal Governmental Role

The federal government has traditionally influenced health of the population by funding research as well as disease and injury control programs and by regulating the safety of products sold in interstate commerce or through the mails. Funding assistance to the states for highways and other programs has in some instances been conditioned on standards for state programs and laws. Authority to provide for the public health and welfare and to regulate interstate

commerce and the postal service are firmly grounded in the U.S. Constitution.

Where constitutionally guaranteed individual, state and corporate rights are violated by laws and regulations, the courts are available to provide relief, but the courts have been very consistent in supporting laws and regulations that protect health where constitutionally guaranteed rights are not in question. These rulings have included the refusal to overturn laws that are designed only to protect the individuals at risk, such as motorcycle helmet use laws, on the grounds that costs to society are too great relative to the individual freedom involved (105).

Laws directed at individual behavior have administrative costs, which may or may not be offset in fines, and costs in loss of freedom, which are unmeasurable in monetary units, and time, which is subject to argument as to whether economically productive or other time is involved. An analysis of the 55 mile per hour speed limit included estimates of time spent driving as a result of the law (39), large in the aggregate and small per trip, but the value of that time depends on the individual involved. To the truck driver or the salesman, the time represents lost income, but the value of driving slower is positive to those who are

viewing scenery or who do not wish to be harassed and endangered by high speed drivers.

Regulation of hazardous products and processes includes increased costs to producers and consumers in some, but not all, cases. One political scientist found that business leaders resented regulation more on the grounds of loss of freedom to run their businesses without interference than on objections to costs (107). Reduced costs of products can sometimes result from regulation. For example, some of the materials used in constructing dashboard knobs and pointed front ends of motor vehicles could be reduced by not allowing them. Since the vehicles are periodically redesigned, the design and manufacturing costs of appropriately phased changes in such designs should be nil. The only cost is in the freedom of the manufacturers to design vehicles as they wish.

The two agencies with major responsibility for regulation of products related to children's injuries, the National Highway Traffic Safety Administration and the Consumer Product Safety Commission, have groups that provide economic analyses of proposed regulations. These analyses are critiqued by affected industries in regulatory proceedings.

Despite the prevalent aversion to governmental regulation in the U.S., the literature indicates that federal government programs and regulations have contributed substantially to reduction of fatal and severe injuries to children. The federal government can further build on that progress in several ways: 1. Require better reporting of injury data by institutions receiving federal funds. 2. Support of research and injury surveillance by state and local health departments as well as university and privately based scientists. 3. Make federal highway or other funds to the states contingent on more consistent state laws, such as reduction in the exemptions in child restraint laws, and devotion of a greater proportion of the funds to scientifically based road improvements. 4. Provide more stringent oversight of the extent of effort and the targets of effort of the regulatory agencies that have authority to regulate the hazards to children. 5. Where authority is lacking, such as regulation of the burn rate of cigarettes, provide the authority.

Recommendations. The following recommendations for federal legislation and oversight are based on the foregoing definition of the problem and review of effective strategies:

1. Withhold Medicare-Medicaid reimbursements from hospitals that fail to provide International Classification of Disease E-codes for injury on at least 90 percent of discharge records. The E-codes are three digit codes specifying the circumstances of injury that are essential for understanding the causes of particular types of nonfatal, severe injuries occurring in particular areas and for determining the degree of success of injury control programs. The data necessary for such coding are often available in the physician's or nurse's notes in patient charts. Perhaps the most efficient way to insure the data's collection is to obtain information on the circumstances of the injury from the patient, family or emergency response personnel at intake.

2. Based on the currently available mortality data and new data from hospital discharges and other epidemiologic studies, direct funds and other resources at the most frequently occurring severe injuries. Programs directed indiscriminately at all injuries regardless of severity may spend inordinate amounts of funds and resources on trivial cuts and bruises. Programs and regulations based on sound epidemiologic evidence and consideration of the outlined principles of choice among technical and implementation strategies are the more likely to be successful. Although

certain injuries are almost unique to children, often programs result in reductions in injury to teenagers and adults, which have higher rates, as well as children. Limiting data collection and program efforts to children in such instances would be relatively inefficient.

3. Any program directed toward changing behavior of persons at risk or persons whose behavior increases risk to others should be tested as to efficacy using stringent experimental-control criteria before being launched on a large scale. There is too much evidence that education or other persuasive approaches can have adverse effects to assume efficacy without adequate research.

4. While the federal government has limited power to enact laws aimed at individual behavior, states have enacted or modified injury control laws in response to federal fund incentives and threats of withholding of federal funds. Identified laws or modifications of laws that would reduce severe injuries, particularly but not exclusively to children, include:

a. Eliminate exemptions in state child restraint and seat belt use use laws.

b. Increase enforcement of child restraint use laws and enactment and enforcement of seat belt use laws.

c. Require head lamp use in daytime by operators of motor vehicles.

d. Repeal right-turn-on-red laws.

e. Increase time of the yellow phase of traffic control lights to 10 percent above design standards for a given intersection.

f. Prohibit operation on private as well as public property of "all-terrain" vehicles, minibikes, and snowmobiles by children not licensed to drive a car.

g. Prohibit the presence of radar detectors in motor vehicles.

h. Require smoke detectors in all residences.

i. Require utility companies to reduce maximum temperatures of water heaters to 120 degrees Fahrenheit during meter reading and limit the maximum temperature of newly manufactured water heaters to that temperature.

j. Require fencing and gates unopenable by children around all swimming pools.

5. Current evidence suggests that reallocation of certain federal expenditures and increased support for specific programs and regulations would reduce severe injuries substantially. Consideration should be given to:

a. Elimination of knobs, tapered dashboards and other points and edges in the interior of motor vehicles that concentrate energy in a crash.

b. Requirement that all federal safety standards now applicable to passenger cars also apply to pickup trucks, vans, and utility vehicles.

c. Promulgation of standards to reduce sharp edges and points on the front of vehicles as well as high bumpers, and increase the energy absorption of hoods and windshield frames to reduce injury to pedestrians.

d. Requirement of all newly manufactured motor vehicles to have a maximum designed speed capability of no more than 60 miles per hour.

e. Requirement of newly manufactured motor vehicles to have installed relays that turn the lights on at ignition.

f. Prohibition of manufacture and sale of radar detectors.

g. Requirement of energy absorbing underride guards on large trucks.

h. Requirement of reflective striping around the outline of large trucks.

i. Reallocation of a larger proportion of highway expenditures to modification of high-risk crash sites using criteria for site selection noted in the research on such sites.

j. Increased funds for surveillance of site characteristics where child pedestrians are injured and identification of site modifications that would reduce collisions with child pedestrians.

k. Restoration of the budgets of the Consumer Product Safety Commission and the National Highway Traffic Safety Administration to compensate for erosion of effort due to inflation.

l. Direct the Consumer Product Safety Commission to set standards for making cigarettes self extinguish when dropped.

Potential for Cost Savings. The enormous societal costs, including federal and state expenditures and tax losses resulting from injury (Table 2), suggest that increased effort in injury control can often be viewed as an investment rather than a cost. Consider the cost of the railroad crossing modifications relative to the reductions in deaths. From 1973 through 1984, approximately $1.3 billion in federal funds was expended for these modifications (38). Deaths at railroad crossings declined

from 1128 in 1974 to 542 in 1984. A conservative estimate of the lives prolonged by this program through 1984 is 4500. This is estimated by taking the proportion of total motor vehicle deaths in each year from 1975 through 1984 if the percent of the total due to railroad crossing collisions in 1974 (2.4%) had continued, and subtracting the actual railroad crossing deaths from that expected number. Using the estimate of quantifiable costs per injury death in Table 2, the cost savings of the railroad crossing modifications through 1984 were approximately $5.2 billions, including $1.1 billion in federal expenditures and revenue losses and $0.5 billion in state expenditures and revenue losses. The program had approximately paid for itself by 1984 in relation to governmental costs and the additional savings from societal losses were additional benefits. Furthermore, the modifications are relatively permanent. Even allowing for maintenance costs, a net cost savings in government expenditures and revenue losses should continue to accumulate from the installations.

Analyses of the costs of many programs and regulations are difficult because they are not simple allocations in the federal budget. The costs of extant motor vehicle safety regulations have been hotly debated (108). It has been claimed that motor vehicle safety standards cost about $300

to $400 per car in the period 1977 to 1981. When the National Highway Traffic Safety Administration surveyed manufacturers as to the price reductions that would be realized if all safety standards were repealed, however, the sales weighted average was only $80 per car in 1978. From 1964, when states required lap seat belts, through 1973, when most of the regulations were in place, the producer price index for cars increased 17 percent while the index for all durable goods increased 35 percent, twice that for cars (105). Thus, major increases in car costs were not apparent in comparison to other durable goods.

Also, whatever the actual charges to consumers, manufacturers have not necessarily used the most cost-effective technology. For example, the requirement for a structure behind the head to prevent injury to the neck in rear-end collisions can be met by increasing the height of the back of the seat or installing an adjustable head restraint. The adjustable restraint costs an average $28 more per car than the high seat back. Yet the manufacturers used adjustable restraints in 72 percent of the cars built from 1969 through 1981. Furthermore, the high seat back is about 72 percent more effective in preventing injury than the more expensive adjustable head restraint (108).

The projected costs of different technologies to conform to proposed regulations vary enormously depending on the assumptions regarding cost per unit and volume. In the debate regarding automatic restraints (seat belts that wrap around occupants when the door is closed or air bags), independent estimates of the costs have been consistently less than manufacturer estimates. In 1981 dollars, the costs of automatic seat belts ranged from $42 to $85 per vehicle in Rabbits and Chevettes, but General Motors said they would cost $114 averaged over all sized cars (109), an estimate disputed as excessive by $28 in an analysis of the manufacturer's investment programs (110).

Air bag costs are substantially sensitive to volume assumptions and unforeseen improvements in technology. During the regulatory debates, estimates of manufacturer costs ranged from $135 to $1,150 in 1981 dollars per car depending on the assumptions used in the analysis (111). Recent developments by suppliers have identified substantial cost savings. Ford's supplier of inflators, Talley Industries, has cut production costs by 40 percent and computer-aided design permits development of customized designs in a "fraction" of the time used in calculating the mentioned estimates (111).

One of the research safety vehicles developed by contract with the National Highway Traffic Safety Administration included improved energy absorption in front ends, air bags, radar brakes, improved side crash protection and front ends softened and tapered to increase protection of pedestrians. The developers estimated that in mass production of a million or more vehicles, the cost of such a vehicle to consumers should be no more than the price of current compact cars (112).

A few other analyses of costs of injury control measures were found in the literature. Some child restraints have a tether on the top that must be attached to the vehicle for maximum benefit. Some vehicles need modification for these tether attachments in the shelf fronting the rear window. An analysis of 51 vehicles indicated that the cost per vehicle for the needed modification varied from $0.60 to $1.97 per vehicle, a total estimated cost of $8.3 million to modify the new vehicle fleet annually, including pickup trucks (113). The costs of modifying pedestrian environments (sidewalks, tunnels, overpasses) has been analysed (114), but the relative effectiveness of these approaches in reducing child pedestrian injury is not known.

A substantial analysis of highway modifications, their costs and effectiveness has been done (115), although not separately for childrens' injuries. Examples of effectiveness include: 60 to 70 percent reductions in collisions by left-turn channelization using curbs or raised bars at intersections, 65 percent reduction in headon collisions by use of no pass stripes, 50 percent reduction of injuries by using guardrail to prevent vehicles leaving the road, 70 percent reduction in crashes at intersections where four-way stop is installed. In contrast, reconstruction, which is far more costly, results in only about a 20 percent reduction in injuries on average (115). The costs of such modifications vary remarkably from one area of the country to another. For example, the variation in cost per square foot to widen concrete bridge decks ranged from $16 to $50 among four states studied (115).

A totally rational allocation of funds and effort would include assessment of need at particular sites, consideration of effectiveness of alternative countermeasures, and choice of countermeasures based on maximum effectiveness per unit cost. Although some such assessments are attempted regarding street and highway changes in the states, the extent to which they take into account crash incidence versus injury severity or are

influenced by other considerations, such as who is selling what product, is unknown. If cost analysis has been done with respect to most countermeasures for childrens' injuries, it is not apparent in commonly used indexes for literature searches.

Because of the complexities involved in cost analyses, a detailed cost-accounting of the various injury control programs and regulations reviewed here is beyond the scope of this paper. It is evident, however, that many programs need only have modest success to pay for themselves. For example, the Centers for Disease Control's allocation of $10 millions per year means that the program will offset its costs in federal government expenditures alone if it results in a reduction in 42 deaths per year and a commensurate reduction in nonfatal injuries. This estimate is obtained by dividing the federal government's losses in assistance payments and revenues, $241,000 for all injuries per death (92) corrected for inflation to 1984 dollars, into the $10 millions per year presently allocated for the CDC program.

References

1. Unpublished data provided by the National Center for Health Statistics, U.S. Public Health Service, Department of Health and Human Services.

2. Susan P. Baker, Brian O'Neill and Ronald S. Karpf, The Injury Fact Book, Lexington, MA: D.C. Heath, 1984.

3. Bernard Guyer and Susan S. Gallagher, An approach to the epidemiology of childhood injuries. In Joel J. Alpert and Bernard Guyer (eds.) Injuries and Injury Prevention, The Pediatric Clinics of North America, Volume 32, 1985.

4. Carol W. Runyan, et al., Childhood injuries in North Carolina. American Journal of Public Health 75:1429, 1985.

5. Allan F. Williams, Observed child restraint use in automobiles. American Journal of Diseases of Children 130:1311, 1976.

6. Keith S. Reisinger and Allan F. Williams, Evaluation of programs designed to increase the protection of infants in cars. Pediatrics 62:280, 1978.

7. Keith S. Reisinger, et al., Effect of pediatricians' counseling on infant restraint use. Pediatrics 67:201, 1981.

8. Richard B. Colletti, A statewide hospital-based program to improve child passenger safety. Health Education Quarterly 11:207, 1984.

9. Allan F. Williams and Joann K. Wells, The Tennessee child restraint law in its third year. American Journal of Public Health 71:163, 1981.

10. Michael D. Decker, et al., The use and efficacy of child restraint devices. Journal of the American Medical Association 252:2571, 1984.

11. Diana Guerin and David P. MacKinnon, An assessment of the California child passenger restraint requirement. American Journal of Public Health 75:142, 1985.

12. Stephen P. Teret, et al., Child restraint laws: an analysis of gaps in coverage. American Journal of Public Health 76:31, 1986.

13. Annemarie Shelness and Jean Jewett, Observed misuse of child restraints. Physicians for Automotive Safety News, Winter, 1984.

14. Daniel Fife, Bernard Rosner and Walter McKibben, Relative mortality of unbelted infant passengers and belted noninfant passengers in air accidents with survivors. American Journal of Public Health 71:1242, 1981.

15. L.A. Foldvary and J.C. Lane, The effectiveness of compulsory wearing of seat-belts in casualty reduction. Accident Analysis and Prevention 6:59, 1974.

16. 285 road deaths averted in four states with seat belt use laws. Insurance Institute for Highway Safety Status Report, August 13, 1986.

17. G.A. Fleischer, An experiment in the use of broadcast media in highway safety. University of Southern California Department of Industrial and Systems Engineering, 1972.

18. Leon S. Robertson, et al., A controlled study of the efffect of television messages on safety belt use. American Journal of Public Health 64:1071, 1974.

19. Kathy Freedman and Jill Lukin, Increasing child restraint use in N.S.W. Australia: the development of a successful mass media campaign. Proceedings of the American Association for Automotive Medicine, 1981.

20. Elmira, N.Y. campaign increases seat belt use to 77 percent. Insurance Institute for Highway Safety Status Report, December 7, 1985.

21. Seat belt use laws: what to expect. Insurance Institute for Highway Safety (news release), December 2, 1986.

22. Air bags in '88 models: the pace picks up. Insurance Institute for Highway Safety Status Report, November 8, 1986.

23. Ben Kelley, GM and the air bag: a decade of delay. Business and Society Review, Fall, 1980.

24. National Highway Traffic Safety Administration, New car assessment program, results as of May 7, 1984.

25. National Highway Traffic Safety Administration, Standards Enforcement Tests Reports Index. Washington, D.C.: U.S. Department of Transportation, 1969-1980 editions.

26. Leon S. Robertson, Automobile safety regulation: rebuttal and new data. American Journal of Public Health 74:1390, 1984.

27. Sam Peltzman, The effects of automobile safety regulation. Journal of Political Economy 83:677, 1975.

28. Leon S. Robertson, A critical analysis of Peltzman's "The effects off automobile safety regulation," Journal of Economic Issues 11:567, 1977.

29. Adrian K. Lund and Paul L. Zador, Mandatory belt use and driver risk taking. Risk Analysis 4:41-53, 1984.

30. Allan F. Williams, Jackson Wong and Brian O'Neill, Occupant protection in interior impacts: an analysis of Federal Motor Safety Standard No. 201. Proceedings of the Twenty-third Conference off the American Association for Automotive Medicine, Morton Grove IL: American Association for Automotive Medicine, 1979.

31. Phyllis F. Agran, Debora E. Dunkle and Diane Winn, Noncrash motor vehicle accidents: injuries to children in the vehicle interior. American Journal of Diseases of Children 139:304, 1985.

32. R.E. Reilly, D.S. Kurke and C.C. Bukenmaier, Jr. Validation of the reduction off rear-end collisions by a high mounted auxiliary stoplamp. Washington, D.C.: National Highway Trafic Safety Administration, 1980.

33. Safety standards. Insurance Institute for Highway Safety Status Report, May 11, 1985.

34. National Safety Council, Accident Facts, Chicago: National Safety Council, 1977-1984 editions.

35. Leon S. Robertson, Federal funds and state motor vehicle deaths. Journal of Public Health Policy 5:376, 1984.

36. Leon S. Robertson and Paul L. Zador, Driver education and fatal crash involvement of teenaged drivers. American Journal of Public Health 68:959, 1978.

37. Leon S. Robertson, Crash involvement of teenaged drivers when driver education is eliminated from high school. American Journal of Public Health 70:599, 1980.

38. William H. Dempsey, Testimony. Extension off the Nation's Highway, Highway Safety, and Public Transit Programs, Hearings before the Subcommittee on Surface Transportation of the Committee on Public Works and Transportation, U.S. House of Representatives, June 5, 1985.

39. Committee for the Study of the Benefits and Costs of the 55 mph National Maximum Speed Limit, 55: A Decade of Experience. Washington, D.C.: Transportation Research Board Special Report 204, National Academy of Sciences, 1984.

40. C.N. Kurucz, An analysis of the injury reduction capabilities of breakaway light standards and various guard rails. Accident Analysis and Prevention 16:105, 1984.

41. Paul H. Wright and Leon S. Robertson, Studies of roadside hazards for projecting fatal crash sites. Transportation Research Record 609, Washington, D.C.: National Academy of Sciences, 1976.

42. Paul H. Wright, et al., Effect of pavement markers on nighttime crashes in Georgia. Atlanta, GA: Georgia Institute of Technology, 1982.

43. Truck crashes for first 8 months of '85 are 6% higher than all of '84. Insurance Institute for Highway Safety Status Report, April 26, 1986.

44. Large trucks should have front brakes. Insurance Institute for Highway Safety Status Report, February 22, 1986.

45. Benjamin Kelley, Underride (film), Washington, D.C.: Insurance Institute for Highway Safety, 1978.

46. William J. Burger, Mark U. Mulholland and Russell L. Smith, Improved Commercial Vehicle Conspicuity and Signalling Systems - Task III Field Test Evaluation of Vehicle Reflectorization Effectiveness. Washington, D.C.: U.S. Department of Transportation Report No. HS 806 923, 1986.

47. Howard Stein, Fleet experience with daytime running lights in the United States - preliminary results. Washington, D.C.: Insurance Institute for Highway Safety, 1984.

48. Paul L. Zador, et al., The effect of signal timing on traffic flow and crashes at signalized intersections. Washington, D.C.: Insurance Institute or Highway Safety, 1984.

49. Rae Newman, Survey of all terrain vehicle related injuries. Washington, D.C.: U.S. Consumer Product Safety Commission, 1985.

50. Lawrence R. Berger, Modern motor milestones. Pediatrics 62:1037, 1978.

51. Stina Sandels, Young children in Traffic. The British Journal of Educational Psychology 40:111, 1970.

52. William H. Yeaton and Jon S. Bailey, Teaching pedestrian safety skills to young children: an analysis and one-year followup. Journal of Applied Behavior Analysis 11:315, 1978.

53. Kenneth Pease and Barbara Preston, Road safety education for young children. British Journal of Educational Psychology 37:305, 1967.

54. David F. Preusser, Pedestrian safety. Proceedings of the Utah Child Injury Conference. Salt Lake City, UT: Utah Department o Health, 1986.

55. Wallace G. Berger, Urban pedestrian accident countermeasures experimental evaluation (vols. I & II). Washington, D.C.: U.S. Department of Transportation Report No. DOT HS 190 2 480, 1975.

56. Sidney Singer, Pedestrian regulation enforcement and the incidence of pedestrian accidents. Washington, D.C.: U.S. Department of Transportation, 1969.

57. Paul Zador, Jack Moshman and Leo Marcus, Adoption of right turn on red: effect on crashes at signalized intersections. Accident Analysis and Prevention 14:219, 1982.

58. S.J. Ashton, Vehicle design and pedestrian injuries. In A.J. Chapman, F.M. Wade and H.C. Foot (eds.) Pedestrian Accidents. London: John Wiley and Sons, 1982.

59. Andrew M. Friede, et al., The epidemiology of injuries to bicycle riders. In Joel J. Alpert and Bernard Guyer (eds.) Injuries and Injury Prevention. The Pediatric Clinics of North America, 1985.

60. Elizabeth McLoughlin and John D. Crawford, Burns. In Joel J. Alpert and Bernard Guyer (eds.) Injuries and Injury Prevention. The Pediatric Clinics of North America, 1985.

61. Robert H. Demling, Burns. The New England Journal of Medicine 313:1389, 1985.

62. U.S. Fire Administration, Residential smoke and fire detector coverage in the United States: findings from a 1982 survey. Washington, D.C.: Federal Emergency Management Agency, 1983.

63. Robert E. Miller, et al., Pediatric counseling and subsequent use of smoke detectors. American Journal of Public Health 72:392, 1982.

64. Richard L. Gorman, et al., A successful city-wide smoke detector giveaway program. Pediatrics 75:14, 1985.

65. Elizabeth McLoughlin, et al., Smoke detector legislation: its effect on owner occupied homes. American Journal of Public Health 75:858, 1985.

66. L.M. Garner, et al., A community action approach for prevention of burn injuries. Bethesda, MD: U.S. Public Health Service, 1969.

67. Elizabeth McLoughlin, et al., Project burn prevention: outcome and implications. American Journal of Public Health 72:241, 1982.

68. Rachel Dardis, Susan Aaronson and Ying-Nan Lin, Cost-benefit analysis of flammability standards. American Journal of Agricultural Economics 60:695, 1978.

69. Clyde A. Bragdon, Jr. Testimony. Prevention of Residential Fire Fatalities - Hearing before the Subcommittee on Science, Research and Technology of the Committee on Science and Technology, U.S. House of Representatives, October 9, 1985.

70. Kenneth W. Feldman, Controlling scald burns. In Abraham B. Bergman (ed.) Preventing Childhood Injuries. Columbus, OH: Ross Laboratories, 1982.

71. John H. Pearn, et al., Drowning and near-drowning involving children: a five-year total population study from the city and county of Honolulu. American Journal of Public Health 69:450, 1979.

72. Daniel A. Spyker, Submersion injury: epidemiology, prevention and management. In Joel J. Alpert and Bernard Guyer (eds.) Injuries and Injury Prevention. Pediatric Clinics of North America, February, 1985.

73. John Pearn, Joseph Brown and Edward Y. Hsia, Swimming pool drownings and near-drownings involving children. A total population study from Hawaii. Military Medicine 145:15, 1980.

74. Alan K. Done, Aspirin overdosage: incidence, diagnosis and management. Pediatrics Supplement:890, 1978.

75. Communication to the author by the Consumer Product Safety Commission, November 18, 1986.

76. Alison M. Trinkoff and Susan P. Baker, Poisoning hospitalizations and deaths from solids and liquids among children and teenagers. American Journal of Public Health 76:657, 1986.

77. Leslie Fisher, et al., Highlight results of the Monroe County poison prevention demonstration project. Veterinary and Human Toxicology 22(Supplement 2):15,1980.

78. Leslie Fisher, et al., Poison control legislation and state governmental funding in the United States. Veterinary and Human Toxicology 27:120, 1985.

79. Robert A. Dershewitz and John W. Williamson, Prevention of childhood household injuries: a controlled clinical trial. American Journal of Public Health 67:1148, 1977.

80. Harvey Kravitz, Prevention of accidental falls in infancy by counseling mothers. Illinois Medical Journal 144:570, 1973.

81. Leslie Fisher, et al., Assessment of a pilot child playground injury prevention project in New York State. American Journal of Public Health 70:1000, 1980.

82. Leslie Fisher, New York leads injury control activities. Journal of Environmental Health 36:213, 1973.

83. Leslie Fisher, Communication and home safety. Proceedings of the 81st Annual Conference of the Association of Food and Drug Officials, 1977.

84. Susan S. Gallagher, et al., A strategy for the reduction of childhood injuries in Massachusetts. The New England Journal of Medicine 307:1015, 1982.

85. Susan S. Gallagher, Paul Hunter, and Bernard Guyer, A home injury prevention program for children. In Joel J. Alpert and Bernard Guyer (eds.) Injuries and Injury Prevention. Pediatric Clinics of North America, February, 1985.

86. M. Douglas Baker, Sally E. Moore and Paul H.Wise, The impact of 'Bottle Bill' legislation on the incidence of lacerations in childhood. American Journal of Public Health 76:1243, 1986.

87. Leon S. Robertson, Community injury control programs of the Indian Health Service: an early assessment. Public Health Reports 101:632, 1986.

88. Jess F. Kraus, Effectiveness of measures to prevent unintentional deaths of infants and children from suffocation and strangulation. Public Health Reports 100:231, 1985.

89. L. Bergner, S. Mayer and D. Harris, Falls from heights: a childhood epidemic in an urban area. American Journal of Public Health 61:90, 1971.

90. C.N. Spiegel and F.C. Lindaman, Children can't fly: a program to prevent childhood mortality and morbidity from window falls. American Journal of Public Health 67:1143, 1977.

91. L. Bergner, Environmental factors in injury control: preventing falls from heights. In A.B. Bergman (ed.) Preventing Childhood Injuries, Columbus, OH: Ross Laboratories, 1982.

92. National Highway Traffic Administration, The Economic Cost to Society of Motor Vehicle Accidents. Washington, DC: U.S. Department of Transportation (DOT HS 806 342), 1983.

93. Economic Indicators, Washington, DC: U.S. Government Printing Office, October, 1986.

94. H.L. Needleman, et al., Deficits in psychologic and classroom performance of children with elevated dentine lead levels. New England Journal of Medicine 300:689, 1979.

95. National Highway Traffic Safety Administration, State and Community Program Area Report, 1984-1985. Washington, DC: U.S. Department of Transportation, 1985.

96. Committee on Trauma Research, Injury in America: A Continuing Public Health Problem. Washington, DC: National Academy Press, 1985.

97. James J. Gibson, The contribution of experimental psychology to the formulation of the problem of safety. In Behavioral Approaches to Accident Research. New York: Association for the Aid of Crippled Children, 1961.

98. William Haddon, Jr., Edward A. Suchman and David Klein (eds.), Accident Research: Methods and Approaches. New York: Harper and Row, 1964).

99. William Haddon, Jr. On the escape of tigers: an ecologic note. Technology Review 72:44, 1970.

100. Park E. Dietz and Susan P. Baker, Drowning: epidemiology and prevention. American Journal of Public Health 64:303, 1974.

101. G. Feck, M.S. Baptiste and C.L. Tate, Jr. An epidemiologic study of burn injuries and strategies for prevention. Albany: New York Department of Health, 1977.

102. William Haddon, Jr. Advances in the epidemiology of injuries as a basis for public policy. Public Health Reports 95:411, 1980.

103. William Haddon, Jr. Reducing the damage of motor vehicle use. Technology Review 77:53, 1975.

104. Leon S. Robertson, Environmental hazards to children: assessment and options for amelioration. In Better Health for Our Children: The Report of the Select Panel for the Promotion of Child Health, Volume IV, Background Papers. Washington, DC: U.S. Department of Health and Human Services, 1981.

105. Leon S. Robertson, Injuries: Causes, Control Strategies and Public Policy. Lexington, MA: D.C. Heath, 1983.

106. Leon S. Robertson, Behavioral research and strategies in public health: a demur. Social Science and Medicine 9:165, 1975.

107. Robert Lane, The Regulation of Businessmen. New Haven, CT: Yale University Press, 1954.

108. Charles J. Kahane, An evaluation of head restraints: Federal Motor Vehicle Safety Standard 202. Washington, DC: National Highway Traffic Safety Administration, 1982.

109. Kenneth E. Warner, Background paper #1: mandatory passive restraint systems in automobiles: issues and evidence. Washington, DC: Office of Technology Assessment, 1982.

110. William Nordhaus, Comments of William Nordhaus on Notice of Proposed Rulemaking on Federal Motor Vehicle Safety Standards: Occupant Crash Protection. Washington, DC: U.S. Department of Transportation, 1981.

111. Automakers step up development of air bag systems. Insurance Institute for Highway Safety Status Report, November 8, 1986.

112. N. DiNapoli, et al., Research Safety Vehicle Phase II, Volume II; Comprehensive Technical Results. Springfiels, VA: National Technical Information Service, 1977.

113. Norman F. Ludtke and Theodore Taylor, Jr. Analysis of Modifications and Costs for Child Seat Anchorages. Washington, DC: U.S. Department of Transportation, 1980.

114. W.G. Scott and L.S. Kagan, A Comparison of Costs and Benefits of Facilities for Pedestrians. Washington, DC: Federal Highway Administration, 1973.

115. William F. McFarland, et al., Assessment of Techniques for Cost-effectiveness of Highway Accident Countermeasures. Washington, DC: Federal Highway Administration, 1979.